Chapter 3: Water Quantity and Flooding

Chapter Contents

3.1 Introduction

Many watersheds in Massachusetts are suffering from low flow and groundwater depletion. Issues related to lack of water have not received as much attention in the Mystic River watershed, although there are areas where low flow is a problem. The primary concerns related to water quantity in this watershed have related to flooding. The watershed is, with some exceptions, very flat and is prone to flooding in a number of locations. This chapter first provides information on water use, and discusses what is currently known about low flow problems.
The next section chapter then presents evidence on the extent and causes of flooding Finally, the chapter recommends actions related to water quantity and flooding.

It is important to note at the outset that there are strong interactions among problems of low flow, flooding and water quality, because all are affected by the quality of stormwater management in the watershed. Developing integrated approaches to managing stormwater that consider all three aspects of watershed health is therefore a high priority for action, as described in Chapter 8. A comprehensive approach will show the co-benefits of Low Impact Development strategies in simultaneously improving water quality, enhancing water retention and flow, and reducing flooding. Without such an integrated evaluation, there is a danger that suboptimal decisions will be made about overall watershed management strategies. In addition, it is critical that a watershed-level approach be used to assess the upstream and downstream impacts of flood management programs, to ensure that flooding problems are not simply relocated to neighboring communities. Currently, most decisions concerning flood control are being considered at the municipal level. Efforts like the Tricommunity Flooding Workgroup (aka the ABC Group) to consider regional solutions to flooding are an important investment in improved watershed management capacity.

3.2 Water Quantity and Use

The Mystic River watershed communities obtain most of their drinking water from the Massachusetts Water Resources Authority (MWRA) system. The MWRA provides water from a system that draws from the Quabbin and Wachusett reservoirs.

Table 3-1 lists the MWRA customer communities and the services provided to each.

Table 3-1: MWRA Customer Communities in the Mystic River Watershed

	Services		MWRA Water Use 2003 (mgd)
	Water	Sewer	
Arlington	x	x	4.330
Belmont	x	x	2.224
Boston	x	x	80.131
Burlington		x	
Cambridge	*	x	
Chelsea	x	x	3.543
Everett	x	x	4.906
Lexington	x	x	5.039
Malden	x	x	5.968
Medford	x	x	5.371
Melrose	x	x	2.361
Reading		x	
Revere	x	x	4.555
Somerville	x	x	6.437
Stoneham	x	x	3.052
Wakefield	p	x	1.866
Watertown	x	x	2.945
Wilmington		x	
Winchester	p	x	0.947
Winthrop	x	x	1.523
Woburn	p	x	1.981

*water- emergency backup only
p = partially supplied
Source: MWRA, http://www.mwra.com/02org/html/whatis.htm#comlist

Table 3-2 lists permitted water withdrawals in the watershed.

Table 3-2: Permitted Water Withdrawals

Facility	Source G = Ground S = Surface	Authorized Withdrawal (mgd)	1999 Average Withdrawal (mgd)
Winchester Water Department	S	1.06*	1.17
Woburn Water Department	G	4.07*	3.11
Kraft General Foods	G	1.0	0.75
Parkview Condominiums	NA	0.36	0.36**
Winchester Country Club	G,S	0.16 (180 days)	never installed

*systemwide withdrawal. ** estimated based on permit application.
Source: MA DEP 2002b.

All of these permitted water withdrawals are in the Aberjona subbasin or the Malden River subbasin.

Fourteen of the 21 communities in the watershed obtain all their **drinking water** from the MWRA. The exceptions are described below.

The City of Cambridge Water Department supplies approximately 15 mgd of drinking water to Cambridge customers. Most of the water is drawn from reservoirs in Cambridge and five other suburban communities, all outside this watershed. Water is piped to the Fresh Pond Reservoir in Cambridge, for storage prior to treatment. The finished water is then pumped to the Payson Park Reservoir in Belmont, from which it flows by gravity through the distribution system (USGS, 1998).

Winchester's water supply comes from three town-owned reservoirs located in the Middlesex Fells Reservation. Winchester also purchases water from the MWRA to supply portions of the town.

Woburn gets approximately 27% of its water from the MWRA system, and the remaining 63% from groundwater, pumped by 9 wells in the Horn Pond subbasin. Woburn lost 24% of its water supply in 1979 when Wells G & H were permanently closed due to contamination. Well E is not used to full capacity, because a farm with livestock is located close to the well and is believed to be a source of elevated nitrate levels in the well.

Burlington's drinking water system contains two separate water treatment plants (with combined capacity of 9.3 mgd) drawing water from both surface sources (the Mill Pond reservoir) and groundwater (the Vine Brook Aquifer).

Wilmington provides drinking water to 99% of its residents and businesses from groundwater sources. The town has been pumping from only 4 of its 9 wells, because

NMDA (N-nitrosodimethylamine) has been detected in the Maple Meadow Brook aquifer wells.

Reading draws its drinking water from groundwater. All of the town's wells are located in the Ipswich River watershed. The town has outdoor watering restrictions in place, due to continuing stress in the Ipswich River basin.

Finally, Wakefield draws 85% of its water from the MWRA and 15% from Crystal Lake.

All of the communities in the Mystic River watershed rely on the MWRA for **wastewater treatment**. Sewage from homes and businesses in the watershed is discharged to local sanitary sewers that are owned and operated by municipal sewer departments. These local sewers transport wastewater into the MWRA interceptor system. The interceptor sewers in turn transport wastewater to the Deer Island Treatment Plant in Boston Harbor, where it receives primary and secondary treatment before discharge through an outfall tunnel into Massachusetts Bay.

Because so much of the watershed's water use draws on sources outside the region, watershed households have not generally confronted problems related to low flow or depleted groundwater. Unlike many Massachusetts communities that rely on local sources for water, for example, the Mystic River watershed communities did not institute any water use restrictions in 2003.

Despite the lack of attention paid to water depletion in the Mystic River watershed, however, there is evidence of low flow problems. Until recently, the only USGS flow gage in the watershed was located on the Aberjona River in Winchester.[1] The Aberjona was therefore the only Mystic subbasin considered in the 2001 Water Resources Commission study of stressed basins. This study classified basins by stress level based on 3 flow metrics: median of annual 7-day low flow, median of annual 30-day low flow, and median of low pulse duration. The Aberjona basin was classified as high stress for 2 of the 3 measures, and therefore classified as highly stressed overall (WRC, 2001).

The extensive development that has occurred in the watershed over the past decades has most likely contributed to depleted groundwater, as well as reduced surface water flows. Increased impervious surface areas result in lower flows particularly in the late summer and early fall, as there is less groundwater recharge during rainfall periods.

During the summers of 2004 and 2005, there were very low flows in Alewife Brook. Further investigation is needed to determine the cause of the low water levels, including reduced groundwater flows, precipitation levels or the operation of the Amelia Earhart Dam.

[1] Another gage has recently been installed on Alewife Brook.

3.3 Flooding

Flood History

Communties throughout the watershed, and especially those bordering the Aberjona, Alewife Brook and the Malden River, have experienced significant flooding problems. Floods are caused by the combination of spring rains and snowmelt, and by heavy rainfall from tropical storms in mid- to late summer. Major floods occurred in the Aberjona and Mystic River basins in 1936, 1955, 1962, 1968, 1969, 1979, 1996, 1998, and 2001. A particularly severe flood in October 1996 was caused by a large rainfall following a period of wet conditions, and the area received a Presidential Disaster Declaration as a result of the flooding. According to information collected for the Aberjona and Mystic Rivers Hazard Mitigation project (DEM and MEMA, 1997), the October 1996 storm had the following effects:

- Arlington residents suffered basement flooding from sewage backups, due to high levels of inflow and infiltration and surcharging. Flooding was most severe in East Arlington and along Mill Brook.

- Medford experienced only isolated flooding, but 200 people were evacuated from an apartment complex and housing project along the Mystic River, and Medford Square was flooded.

- An estimated 600 homes in Winchester were damaged by flooding from Horn Pond Brook and the Aberjona River. The high school and the downtown area were also flooded.

- Woburn experienced flooding from high water in Horn Pond Brook. The City was unable to draw down water behind the Horn Pond Dam sufficiently to prevent the flooding.

Route 2 and Alewife Brook Parkway have been closed due to Alewife Brook flooding three times in the last six years (October 1996, June 1998 and March 2001.)

The Amelia Earhart Dam was constructed in 1965, and had large pumps installed in the 1970s. The dam is operated to maintain water elevations in the basin above the dam, by sluicing water out of the basin at low tide and pumping water into the harbor during high tides. Water levels are drawn down in anticipation of storms to control flooding. The need to maintain adequate levels for boating and to protect spawning fish places constraints on how low the water levels can be taken before large storms.

Flooding below the Amelia Earhart Dam is generally caused by coastal storm surges, rather than by freshwater flows. Major coastal flooding occurs during extra-tropical storms called Nor'easters and hurricane surges, generally in the fall and winter. The Army Corps of Engineers has modeled surge inundations for the lower basin (US ACOE 2004). This study should be reviewed for information on the frequency and severity of flooding problems in the coastal areas of the watershed.

Current Status

The most recent Federal Emergency Management Agency (FEMA) maps of the 100 and 500 year floodplains in the basin date from 1977-1980. Since that time, freshwater (riverine) floodplains are likely to have expanded because of continued loss of pervious surfaces and increased intensity of extreme rainfalls due to climate change. FEMA is currently conducting a study to update the floodplain maps for the Mystic River watershed, due to be finished in Spring 2004. Early indications are that the flood levels will be substantially higher, and the floodplains therefore larger, than reflected in current maps, at least in some areas. Until the update is completed, the 1977-1980 maps are still considered the "official" floodplain maps for FEMA regulatory purposes. The information summarized below is based on these maps, and therefore is likely to understate the extent of the floodplains in the watershed.

Figure 3-1 shows the 100 year and 500 year floodplains currently mapped by FEMA in the watershed. Figures 3-2 through 3-10 show the floodplains in each subbasin. Table 3-3 shows the land area flooded in the 100 year flood in each sub-basin floodplain. The 100 year coastal floodplains are either the VE or A zones.

As can be seen in Figure 3-1, there is flooding along the entire Mystic River and its major tributaries.

The damage caused by flooding depends on what kinds of land uses are affected. Table 3-3 shows that the land uses most affected by 100 year flooding varies by subbasin:

- Aberjona - industrial;
- Alewife Brook -- residential;
- Chelsea Creek - industrial and transportation;
- Horn Pond - residential;
- Malden River - commercial and residential;
- Mill Brook - commercial;
- Mystic River 1 - residential;
- Mystic River 2 - industrial; and
- Upper Mystic Lake/Lower Mystic Lake - residential.

In the 100 year floodplain, the Mystic River 1 subbasin, with the confluence of the Mystic River and Alewife Brook, accounts for the largest area of commercial flooding. The largest amount of industrial flooding is in the Aberjona River and the Mystic 2 subbasin, and the largest amount of residential flooding is in the Horn Pond and Mystic 1 subbasins.

Table 3-3: Areas in 100-Year Floodplains by Subwatershed and Land Use (square miles)

Subwatershed	Total Subwater-shed Area	Area in 100-Year Floodplain (square miles)						
		Commercial	Industrial	Open Space	Recreational	Residential	Transportation	Total in Floodplain
Aberjona	16.0	0.02	0.06	0.31	0.01	0.02	0.08	0.5
Alewife	7.0	0.00	0.01	0.24	0.08	0.03	0.00	0.36
Chelsea Creek	3.5	0.02	0.03	0.06	0.02	0.02	0.19	0.34
Horn Pond	10.0	0.01	0.00	0.32	0.01	0.08	0.00	0.42
Malden River	9.9	0.04	0.02	0.12	0.05	0.04	0.00	0.27
Mill Brook	5.2	0.03	0.00	0.13	0.04	0.02	0.00	0.22
Mystic River 1	7.9	0.07	0.01	0.12	0.06	0.08	0.02	0.36
Mystic River 2	3.2	0.00	0.06	0.05	0.01	0.00	0.08	0.2
Upper & Lower Mystic Lakes	3.8	0.00	0.00	0.47	0.01	0.03	0.00	0.51
Total	66.5	0.19	0.19	1.82	0.29	0.32	0.37	103.18

Source: Paul Kirshen, Tufts University, analysis based on MassGIS data layers.

Mystic River 1 also has the largest total 100 year flooded area of industrial, commercial, and residential land combined (0.16 square miles, sqm), followed by Aberjona (0.10 sqm), Malden River (0.10 sqm), Horn Pond (0.09 sqm), Chelsea Creek (0.07 sqm), Mystic River 2 (0.06 sqm), Mill Brook (0.05 sqm), Alewife Brook (0.04 sqm), and Upper Mystic Lake/Lower Mystic Lake (0.03 sqm).

The highest percent of total area flooded in the 100 year flood are the Chelsea Creek, Mystic 1, and Mystic 2 subbasins, all with approximately 2 percent of their land area flooded. The other basins have approximately 1 percent of their area in the 100 year floodplain.

Despite the relatively larger portions of the area in the floodplain in the Chelsea Creek or Mystic 2, most of the attention given to flooding to date has been in the Upper and Middle watershed. This may reflect the fact that much of the affected area in the Lower Mystic is industrial as opposed to residential. It is also possible that more frequent floods are occurring in the freshwater areas of the watershed, causing more frequent damage than coastal floods. More investigation is clearly needed, however, to assess the problems caused by flooding in the Lower Mystic subbasins.

The floodplains are distributed differently in the different subbasins, as well as affecting different types of land uses. Floodplains are concentrated in some areas, and located along most of the river in others. In addition, each area is likely to differ in the factors contributing to flooding and the available options for managing flooding (storage, removal of constrictions, preserving or reclaiming pervious surfaces, etc.) These differences suggest that different flood management strategies might be needed in different areas. It is also be important, however, to look at hydrologic interconnections among the basins, since steps taken to reduce flooding in one community could increase flooding problems elsewhere. In addition, there may be opportunities to address flooding cost-effectively through cooperative regional efforts – for example, with several municipalities purchasing a piece of land that provides stormwater storage for all the communities.

There is substantial uncertainty about the specific factors contributing to flooding in various parts of the watershed – in particular, the extent to which constrictions contribute to flooding. Street flooding may occur because the hydraulic capacity of the drainage system in some locations is inadequate to convey the storm runoff. This is reported as a major concern in North Cambridge (Jacobs Consulting Services 2000) and Winchester (CDM, 1999), for example. Additional investigation is needed throughout the watershed to develop a comprehensive understanding of the factors causing flooding and the potential solutions. Some efforts in this direction are described later in this chapter.

Flooding presents a public health concern, as well as causing safety hazards and property damage, in many areas of the watershed. Floodwaters can enter residential yards and basements where rising water levels in sewer pipes cause backups into basement drains, sinks and toilets, or via overland flooding. The floodwaters may be contaminated with sewage from Combined Sewer Overflows, as well as sewer surcharges and overflows through manholes in separate sewer systems. CSOs discharging into Alewife Brook are a particular concern in East Arlington and North Cambridge, for example. Data presented in Chapter 4 show that wet weather bacteria contamination is a problem throughout the watershed.

Trends

The Mystic River watershed is generally quite flat, except near some of the basin boundaries where there are significant elevations (for example, the Fells in the east). As a result, flooding has always been a problem in this basin. Although several relatively large engineering projects have been constructed to attempt to manage water levels, flooding remains a problem and may get worse in the future.

While there may be disputes as to the specific causes of increased flooding problems, there is an emerging view that flooding is in fact gotten worse in the Mystic River watershed. For example, Steve Kaiser's studies of flooding data for the Alewife area suggest that the 10-year flood elevation is 6.5 feet today, compared with FEMA's estimate for a 10-year flood 20 years ago of 5.6 feet. (Kaiser, 2002b) As described in Chapter 5, considerable open space has been lost in the basin over the past decades. The increase in impervious surfaces associated with this development has resulted in increased runoff, faster runoff and increased flooding over time.

It is now well accepted that long-term climate change has also increased the intensity of extreme rainfall events in the basin and will continue to in the future. One experimental estimate by Kharin and Zwiers (2000) found that, by 2050, the frequency of the present 100 year storm could decrease to 50 years and the present 500 year storm to 100 years. By 2100, the frequency of the present 100 year storm could decrease to 25 years and the present 500 year storm to 40 years. Coastal flooding will also become more severe in the future due to sea level rise caused by global warming and land subsidence. An increase of 2 to 3 feet in sea level is possible within 100 years (US EPA). A 1 foot rise would increase the frequency of the present 100 year flood to 10 years, and the present 500 year flood to 100 years (US Army Corps of Engineers). (These studies are cited in a comprehensive study of global climate change impacts on flooding in the Boston area by Kirshen et. al. 2004).

Potential for increased flooding is also caused by work now underway to reduce Combined Sewer Overflows during storm events. Actions taken to separate storm drains from the sanitary sewers in North Cambridge will reduce CSOs by removing stormwater from the sanitary sewers, but will increase the amount of stormwater being discharged to surface waters. Cambridge has proposed a constructed wetland in the Alewife Reservation to store the additional stormwater runoff resulting from the sewer separation.

Potential Solutions to Flooding

A number of studies have been completed or are now underway on flood management in the watershed (CDM, 2003). This section summarizes the most recent efforts.

FEMA is currently updating floodplain maps for the watershed (Galvin, 2003). The new maps are based on updated rainfall data and improved topographic information, and are expected to show a larger 100-year floodplain in some areas than the current maps show. An interim study by the MDC (now the DCR) developed updated floodplain maps for the Alewife area, using FEMA's current flood level estimates and improved information on topography, which showed an expanded 100-year floodplain.

The most comprehensive recent studies in the Mystic Basin are the 1999 CDM study of the Aberjona for the Town of Winchester and the 2002-2003 hydrology and hydraulic study (H&H) by CDM for the Mystic River from the Mystic Lakes to the Amelia Earhart Dam.

CDM's 1999 study for Winchester addressed causes and possible management plans for flooding on the Aberjona River. The study concluded that the spillway elevation at Upper Mystic Lake dam does not significantly impact flooding in the basin upstream of the Wedgemere train station and thus is not a cause of concern. The study recommended that the town work with Woburn on the operation of Horn Pond dam during storms. The major cause of flooding was found to be an overall lack of hydraulic capacity in the river. To remedy this, CDM recommended 16 modifications to structures or channels in the Aberjona.

The Town of Winchester submitted a $13 million set of flood control projects for MEPA review in May 2003, based on the CDM recommendations. The town's request for a Phase I waiver for the entire project was denied, but a waiver has been granted for addition of a large storm pipe to an existing bridge abutment. The overall plan was criticized by some commenters as relying too heavily on engineering solutions. The town is now in the process of preparing a comprehensive Environmental Impact Review for its flood management plan, and may be considering additional alternatives beyond those proposed in the original MEPA filing, including land use policies and regional storage options.

The CDM (2003) H&H modeling study report concluded that:

- The Upper Mystic Lake dam and outlet works configuration do not provide sufficient storage to attenuate large stormwater inflows. Changes in the outlet works that would allow lowering lake levels at the beginning of large storms would be an effective way to lower flood levels in and around the lake, however.

- No major hydraulic constrictions were found on the Mystic River from Upper Mystic Lake Dam to the Amelia Earhart Dam that would cause high head losses and elevated flood profiles.

- Observed constrictions at the Craddock Dam might have been due to submerged debris at the dam. The DCR has since removed this debris.

The modeling study also found constriction-related head losses in Alewife Brook at the Broadway and Massachusetts Avenues bridges. However, the combined losses are only 0.4 feet for a 50 year flood. Widening of these bridges might slightly reduce the severity and frequency of flooding along Alewife Brook and Little River, but would be very expensive.

The second phase of the CDM H&H study will focus upon rehabilitation or replacement of the Upper Mystic Lake dam and its possible operations for flood management.

There have been three major efforts to address flooding problems on a regional basis in recent years. Following the October 1996 flood, an effort was instituted by the Town of Winchester to develop a coordinated approach to flood hazard reduction in the Upper Mystic and Aberjona basins. This effort led to signing of a formal Joint Powers Agreement among the towns of Arlington, Burlington, Lexington, Medford, Reading, Stoneham, Wilmington, Winchester, and Woburn, forming the Upper Mystic River Watershed Board. A multi-stakeholder effort received support from FEMA's Project IMPACT program. While the effort resulted in development of additional information on flooding problems and solutions, no coordinated regional management plan for flooding resulted from the work of this group. (Miriam Anderson, FEMA, personal communication, April 22, 2003).

A second regional body, the Tricommunity Flooding Work Group, was formed in 2002. It consists of a formal Joint Powers Agreement among Arlington, Belmont and Cambridge, as well as a larger informal group that includes residents and local organizations as well. The group's goal is to address flooding problems in the Alewife subbasin. This group held a public forum in April 2003, and has been investigating what is known and not known about the causes and solutions to Alewife area flooding. As part of this effort, engineers from the three municipalities have been meeting as a group to share information. This group issued its progress report in the June 2004, and is now working on implementing some of the recommendations. These include additional gaging to improve flood level information, and encouraging improved storm drain maintenance in the three municipalities and by regional agencies (the DCR and MWRA).

Third, the Metropolitan Area Planning Council (MAPC) is conducting a Pre-Hazard Mitigation Study which includes a number of communities in the lower watershed. This study is assessing potential damages from flooding and developing plans to mitigate damages.

There have also been a series of more focused flood studies on particular problems. As reported by Kaiser (2002b), these include EIR/EIS reports for some developments and the Jacobs Consulting Services (2000) report for drainage and flooding issues in the North Cambridge area of Alewife Brook.

Data Gaps

The most significant data gap hindering improved understanding of flooding and floodplain management is the lack of reliable flood elevation measurements for much of the watershed. Steve Kaiser has documented significant discrepancies and gaps in the available data on flood elevations in the Alewife subbasin (Kaiser, 2002). He notes that measurements of flood levels have been irregular and often undocumented. The following are some of the available flow and flood level data:

- The longest source of flow data is the Aberjona Gage, which has provided continuous flow records since 1939. This has been the only long-term site in the basin.

- A new gage was recently installed by USGS on Alewife Brook.

- The City of Cambridge has had continuous stage recorders at Alewife Brook at Broadway since 1998.

- The MDC/DCR records the continuous pool elevation at the Amelia Earhart Dam.

- The City of Somerville- MyRWA-Tufts EMPACT study has real-time reporting of stages at 5 locations in the basin during the river recreation season from approximately April to October starting in 2002. Locations include Sandy Beach, High Street, Alewife Brook near the Mystic Confluence, Blessing of the Bay Boathouse, and the Amelia Earhart Dam.

- In 2003, Tufts also started a nutrient management study of the watershed including and above the Upper Mystic Lake, where some stage-discharge measurements will be taken for several years.

- Kaiser (2002) reports that the Town of Belmont has stage measurements for Little Pond since 1928 but they have not been reviewed in recent years.

- The US Army Corps of Engineers collected some high water marks resulting from the October 1996 storm (then estimated by the USGS to have a recurrence interval of 50 years). Some have questioned the accuracy of the Corps data (Kaiser, 2002).

In contrast to the lack of consistent data on flood levels, good sources of rainfall data are available for use in evaluating trends in the relationship between rainfall and flooding. The best source of rainfall data is the US National Weather Service site in Boston (covering 130 years). There is also a rain gage at the Aberjona USGS streamflow gage, and another at Muddy River (which is outside this watershed but close by, and reported to be a particularly accurate source.) The Massachusetts Water Resources Authority has been collecting data at some sites in the basin for several years. Finally, there are some data collected by the former State Climatologist in Reading.

Hourly sea level records in Boston are available from The National Oceanographic Survey since at least 1920.

3.4 Priorities for Action

The available information suggests that flooding is the most important hydrologic problem in the Mystic River watershed. The following priority goals were identified related to flooding and low flow.

- Development of integrated regional water management strategies, that consider combined impacts on flooding, water quality, and flow and that take into account the future impacts of global climate change on infrastructure and water management.

- Improved dam operation and maintenance, to improve flood control as well as to allow improved fish passage.

- Incorporating the findings of the update FEMA floodplain maps and the MAPC Prehazard Mitigation Planning studies in improved municipal floodplain management.

- Efforts to characterize low flow problems and develop strategies to address these problems.

Specific actions to achieve these goals are recommended in Chapter 8.